Working Document No. 12 to the
Arctic Fisheries Working Group
21 – 29 April 2008

Modelling maturity ogive for Northeast Arctic saithe

by

Åge Fotland and Sigbjørn Mehl
Institute of Marie Research,
P.O. Box 1870 Nordnes, N-5817 Bergen, Norway

Background

Until 1995 knife-edge maturity at age 6 was used for this stock. In the 1996-2004 assessments, an ogive based on analyses of spawning rings in otholiths from the period 1973-1994 was applied for all years. The analysis showed a lower maturation in the last part of the period, and some extra weight was given to this part when an average ogive was calculated. Prior to the 2005 WG a large number of otholiths with missing information on spawning rings were re-read, and new analyses were done for the period 1985-2004. The average for the period 1985-2004 is presented in the text table below together with the old ogive applied.

Age group	2	3	4	5	6	7	8	9	10	11+
Old ogive	0	0	0.01	0.55	0.85	0.98	1	1	1	1
1985-2004	0	0	0.08	0.51	0.76	0.90	0.94	1	1	1

In the last part of the period the maturity at age has decreased somewhat and in 1997-2001 there was a lower maturation for age groups 4-8, especially in 1998 the maturation was low. The question was whether to use a new fixed average maturity ogive for the whole period after 1985, an annual ogive, a running average or try to model the maturity ogive. If one completely trusts the otolith-based method, an annual ogive would probably be the best. But the determination of spawning rings is still

uncertain and variable between otolith readers and the effect of errors on SSB-estimates and advice may be large. The maturity at age based on spawning rings for the period 1996-2000 was compared with maturity at age based on gonad development measured during the acoustic survey in October (Aglen *et al.* 2008). For the youngest maturing age groups (4 and 5) a lower maturation was estimated based on gonad development at the survey time in October than based on spawning rings the following year (age 5 and 6). But a similar reduction in maturation in the period 1996 to 1999 was observed in both series. For age 6-7 the differences in estimated maturation were less, while for age 7-8 the reduction in maturation was smaller in the gonad based data (age 7) compared to the spawning ring based (age 8). Since both the spawning ring based maturation and the gonad development based one showed similar trends to some degree, the 2005 WG decided to use a 3-year running average after 1984 (2-year average for the first and last year). This method was also applied by the 2006 and 2007 AFWG. Table 1 presents the 3-year running average maturity ogives for the period 1985-2006.

Table 1. NEA saithe. 3-year running average maturity ogive 1985-2006.

	Age group									
Year	2	3	4	5	6	7	8	9	10	11+
1985	0	0	0.04	0.76	0.87	0.92	1	1	1	1
1986	0	0	0.03	0.76	0.89	0.95	1	1	1	1
1987	0	0	0.03	0.63	0.88	1	1	1	1	1
1988	0	0	0.09	0.56	0.74	1	1	1	1	1
1989	0	0	0.16	0.56	0.64	1	1	1	1	1
1990	0	0	0.17	0.66	0.62	0.91	1	1	1	1
1991	0	0	0.12	0.72	0.75	0.9	1	1	1	1
1992	0	0	0.05	0.64	0.84	0.89	1	1	1	1
1993	0	0	0.03	0.54	0.91	0.98	1	1	1	1
1994	0	0	0.09	0.5	0.85	0.97	1	1	1	1
1995	0	0	0.14	0.53	0.81	0.9	0.98	1	1	1
1996	0	0	0.14	0.5	0.73	0.84	0.97	1	1	1
1997	0	0	0.11	0.42	0.59	0.74	0.82	1	1	1
1998	0	0	0.08	0.27	0.53	0.69	0.76	1	1	1
1999	0	0	0.04	0.28	0.54	0.72	0.75	1	1	1
2000	0	0	0.05	0.27	0.7	0.81	0.88	1	1	1
2001	0	0	0.05	0.38	0.78	0.94	0.93	1	1	1
2002	0	0	0.07	0.45	0.86	0.94	0.96	1	1	1
2003	0	0	0.09	0.46	0.87	0.95	0.93	1	1	1
2004	0	0	0.13	0.55	0.84	0.92	0.9	1	1	1
2005	0	0	0.17	0.61	0.85	0.92	0.87	1	1	1
2006	0	0	0.17	0.73	0.86	0.90	0.89	1	1	1

In later years there has been a southwards shift in the distribution of saithe (Aglen *et al.* 2008) and the biological sampling from the southern part of the distribution area has increased somewhat. Since 2002 the commercial reference fleet have contributed to this sampling. A higher maturation for ages 4 and 5 have been observed in theses samples compared to samples from the northern part of the distribution area. The 3-year running average ogive used in the assessment is not weighted by abundance, and the increased number of samples in the south has contributed more in later years. Both maturation at age 4 and 5 and SSB might therefore have been overestimated in this period. It was therefore decided to try to model the maturity ogive for Northeast Arctic saithe, taking abundance by area into account.

The maturity at age is modelled as a function of the TSB. This is the same model as used in the evaluation of the harvest control rule for Northeast Arctic cod in the simulations with density dependent maturation (Bogstad *et al.* 2004). For NEA cod maturity at age is also modelled as a function of weight at age in the stock (Kovalev and Bogstad 2005), but this method was not tried for saithe since we only have catch weights.

Methods

Annual maturity ogive data based on spawning rings is applied in the modelling. The proportion of mature saithe in each age group is calculated as the proportion of saithe where the spawning zone is determined vs. the total number of specimen in that age group. The proportion is the weighted vs. the number of fish sampled in the annual Norwegian coastal survey (Aglen *et al*. 2008) by statistical area 06+07+30+34+35+50 and other areas (Tables 2 and 3). The commercial fleet is taking samples from the ongoing fishery, and may be variable from year to year depending on factors as quotas of saithe and other fish species, availability and catchability. We therefore weighted the samples to represent distribution trends observed in the survey. The final XSA from AFWG 2007 were used for computing TSB.

We suggest the following model for density-dependent maturation:

$$p_{a,y} = \frac{1}{1+e^{-\alpha_a (TSB_{50,a} - TSB_{y-1})}} \quad (1)$$

where $p_{a,y}$ is the proportion of mature saithe at age *a* in year *y*. We first fitted values for α_a and $TSB_{50,a}$ separately for each age group (3-10). This gave a total sum of squares ($\sum_{a,y}(p_{a,y}^{\mathrm{mod}} - p_{a,y}^{obs})^2$) of 1.8.

Also, the lambda parameter at age 8 became unrealistically high when fitting age-specific values of α_a and $TSB_{50,a}$ .The average lambda for age groups 5-7 are used for all age groups.

With parameter values $lambda_a$ and Tsb50 as follows.

age	lambda	Tsb50
2		
3		
4	0.0726	-58.4432
5	0.0726	-5.33516
6	0.0726	26.93691
7	0.0726	44.7577
8	0.0726	197.3517
9	0.0726	173.5741
10		

Table 2. Proportion mature in area (06+07+30+34+35+50, other area).
Years 1995-2006 are shown.

		Age														
Year	area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1995	other	9	83	603	862	1021	1215	305	28	9	8	17	28	2	0	1
1995	other	0	0	0	28	350	1052	301	28	9	8	17	28	2	0	1
1995	06 07	0	32	188	314	247	186	42	6	3	1	1	0	2	0	0
1995	06 07	0	0	0	3	75	141	42	6	3	1	1	0	1	0	0
1996	other	0	26	128	840	744	1219	1252	200	23	11	4	6	9	1	0
1996	other	0	0	0	2	166	807	1063	197	23	11	4	6	9	1	0
1996	06 07	1	46	105	220	170	202	266	137	24	15	11	2	0	1	1
1996	06 07	0	0	1	24	79	191	264	137	24	15	11	2	0	1	1
1997	other	0	33	541	602	2461	1308	1433	652	60	12	2	4	4	6	2
1997	other	0	0	0	4	108	601	1314	649	60	12	2	4	4	6	2
1997	06 07	0	22	228	205	371	190	182	124	49	3	8	4	4	0	4
1997	06 07	0	0	7	30	126	76	148	123	49	3	8	4	4	0	4
1998	other	0	49	247	1004	826	2401	586	337	172	24	3	1	0	0	2
1998	other	0	0	0	0	37	404	368	260	119	19	2	1	0	0	2
1998	06 07	0	30	61	235	147	197	159	151	94	28	2	1	2	0	4
1998	06 07	0	0	0	11	34	122	152	150	94	28	2	1	2	0	4
1999	other	1	49	717	1022	2000	1030	1707	268	169	63	1	2	1	1	2
1999	other	0	0	0	3	80	308	1008	247	156	60	1	1	0	0	2
1999	06 07	0	27	115	104	166	76	177	89	97	84	17	6	0	0	0
1999	06 07	0	0	0	5	52	44	129	85	89	81	17	4	0	0	0
2000	other	13	74	361	2039	956	1323	779	933	211	152	42	11	1	0	3
2000	other	0	0	0	7	77	538	699	901	209	148	39	9	1	0	2
2000	06 07	0	46	138	243	69	153	105	436	209	225	63	11	3	0	3
2000	06 07	0	0	0	1	17	103	100	434	209	225	63	11	3	0	3
2001	other	0	134	584	694	2343	834	731	313	331	74	45	11	1	0	1
2001	other	0	0	0	13	197	515	691	308	326	72	43	11	1	0	1
2001	06 07	1	53	161	160	284	69	157	87	138	54	36	10	1	0	0
2001	06 07	0	0	0	0	49	59	152	82	135	54	34	8	1	0	0
2002	other	1	21	555	1036	926	2037	344	228	103	102	25	15	2	4	1
2002	other	0	0	0	4	96	1723	326	225	103	101	25	15	2	4	1
2002	06 07	1	29	108	215	112	187	62	98	82	110	61	31	18	4	3
2002	06 07	0	0	0	2	43	150	61	97	82	110	61	31	18	4	3
2003	other	99	142	246	2134	820	509	796	162	112	58	62	30	10	3	3
2003	other	0	0	0	5	97	423	780	162	112	58	62	29	10	3	3
2003	06 07	4	42	62	143	140	111	156	40	67	53	48	32	13	9	2
2003	06 07	0	0	0	1	49	104	152	40	66	52	48	32	13	9	2
2004	other	3	270	243	416	2155	789	366	451	117	40	26	30	4	5	2
2004	other	0	0	0	5	256	584	352	444	117	40	26	30	4	5	2
2004	06 07	0	31	74	99	105	112	100	165	52	65	51	33	11	8	5
2004	06 07	0	0	0	4	33	101	98	159	51	65	51	32	11	8	5
2005	other	24	35	628	450	530	1572	608	204	185	46	8	12	10	8	3
2005	other	0	0	0	8	171	1215	583	202	185	46	8	12	10	8	3
2005	06 07	6	15	171	137	67	111	219	219	354	54	53	34	21	5	9
2005	06 07	0	0	0	4	32	104	219	219	351	54	53	32	21	4	9
2006	other	16	49	66	2025	717	587	1028	425	136	69	16	11	3	7	6
2006	other	0	0	0	49	280	528	1009	424	136	69	16	11	3	6	6
2006	06 07	3	90	74	208	103	77	157	143	104	127	29	25	16	9	4
2006	06 07	0	0	0	21	78	70	157	139	103	127	29	25	16	9	4

Table 3 Proportion mature by gonads, in autumn cruise (1985-2006), same grouping as in table 2. Years 1995-2006 are shown.

		Age														
Year	Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1995	other	2	2	44	327	320	263	123	18	3	0	2	0	0	0	0
1995	other	0	0	0	3	18	131	110	18	3	0	2	0	0	0	0
1995	06 07	0	0	31	110	111	88	47	8	1	1	0	1	0	1	0
1995	06 07	0	0	0	1	29	53	46	8	1	1	0	1	0	0	0
1996	other	0	0	25	75	242	124	80	42	8	1	0	0	2	0	0
1996	other	0	0	0	0	1	22	37	34	8	1	0	0	2	0	0
1996	06 07	0	1	46	75	98	50	38	26	6	2	1	1	0	0	0
1996	06 07	0	0	0	0	4	26	32	26	6	2	1	1	0	0	0
1997	other	0	0	22	172	157	430	98	63	26	1	4	0	0	2	1
1997	other	0	0	0	0	4	44	54	49	25	1	3	0	0	2	1
1997	06 07	0	0	22	123	64	134	40	35	13	4	1	0	0	0	1
1997	06 07	0	0	0	0	4	40	28	31	12	3	1	0	0	0	1
1998	other	0	0	49	102	207	133	231	24	18	4	0	0	0	0	0
1998	other	0	0	0	1	2	16	70	14	16	4	0	0	0	0	0
1998	06 07	0	0	30	51	120	44	46	15	16	5	1	0	0	0	0
1998	06 07	0	0	0	1	6	8	27	14	16	5	1	0	0	0	0
1999	other	23	1	49	305	190	164	81	111	17	16	13	0	1	0	1
1999	other	0	0	0	2	38	72	53	95	16	16	13	0	1	0	1
1999	06 07	0	0	26	65	21	43	18	29	20	5	1	0	0	0	0
1999	06 07	0	0	0	0	6	15	14	24	19	5	1	0	0	0	0
2000	other	0	13	62	114	165	58	32	34	18	6	8	5	4	1	3
2000	other	0	0	0	0	29	39	25	33	16	6	8	5	4	1	3
2000	06 07	0	0	35	34	66	10	25	11	11	8	7	4	0	1	0
2000	06 07	0	0	3	1	11	7	23	10	11	8	7	4	0	1	0
2001	other	0	0	125	299	149	204	49	38	15	20	8	6	0	0	0
2001	other	0	0	0	0	16	94	36	32	15	20	8	6	0	0	0
2001	06 07	0	1	52	131	72	101	19	25	14	15	8	8	4	0	0
2001	06 07	0	0	0	1	14	47	14	24	14	15	8	8	4	0	0
2002	other	34	1	17	209	146	68	77	20	4	5	5	2	1	0	0
2002	other	0	0	0	1	6	27	56	19	3	5	5	2	1	0	0
2002	06 07	0	1	27	83	119	34	45	11	12	10	9	4	3	2	0
2002	06 07	0	0	0	0	13	13	38	8	11	10	8	4	3	1	0
2003	other	1	99	141	171	286	130	53	55	22	8	9	12	4	1	2
2003	other	0	0	1	1	29	46	45	54	21	6	9	12	4	1	2
2003	06 07	0	4	42	58	85	46	14	27	3	8	5	2	2	1	0
2003	06 07	0	0	0	0	15	20	14	26	3	8	5	2	2	1	0
2004	other	3	3	269	205	135	169	70	31	27	23	6	8	4	2	2
2004	other	0	0	0	0	4	67	53	30	27	23	6	8	4	2	2
2004	06 07	6	0	31	71	88	56	34	14	11	5	1	2	2	1	0
2004	06 07	0	0	0	2	19	39	33	13	11	5	1	2	2	1	0
2005	other	6	24	34	294	133	65	77	34	21	20	9	2	1	1	0
2005	other	0	0	0	3	16	24	48	28	20	20	8	2	1	0	0
2005	06 07	10	6	13	70	45	24	29	19	6	6	3	3	2	0	1
2005	06 07	0	0	0	0	8	15	25	15	5	6	3	3	2	0	1
2006	other	2	16	48	48	194	62	38	52	24	12	10	8	8	2	9
2006	other	0	0	0	0	8	8	23	51	23	12	10	8	8	2	9
2006	06 07	7	3	86	42	120	69	43	50	63	18	14	5	4	3	1
2006	06 07	0	0	1	1	16	50	39	49	60	18	14	5	4	3	1

Results

The model gives the maturity ogive shown in Table 4 and the model fit for ages 4-9 is shown in Figure 1. Figure 2 shows the average modelled maturity ogive for 1985-3006. Figure 4 shows the Norwegian statistical regions used to group areas.

Table 4. Modelled maturity by age groups.

YEAR	1	2	3	4	5	6	7	8	9	10	11+
1985	0	0	0	0.0179	0.3328	0.8539	0.9657	1	1	1	1
1986	0	0	0	0.0235	0.3532	0.8742	0.963	1	1	1	1
1987	0	0	0	0.0233	0.3808	0.8798	0.965	1	1	1	1
1988	0	0	0	0.0123	0.3829	0.8879	0.965	1	1	1	1
1989	0	0	0	0.0151	0.2537	0.881	0.9661	1	1	1	1
1990	0	0	0	0.0216	0.2805	0.8411	0.9658	1	1	1	1
1991	0	0	0	0.0236	0.359	0.86	0.9585	1	1	1	1
1992	0	0	0	0.0244	0.3719	0.8702	0.9605	1	1	1	1
1993	0	0	0	0.0116	0.3766	0.8823	0.9629	1	1	1	1
1994	0	0	0	0.0039	0.2174	0.8844	0.9664	1	1	1	1
1995	0	0	0	0.0094	0.1251	0.825	0.9661	1	1	1	1
1996	0	0	0	0.0121	0.1714	0.6994	0.9564	1	1	1	1
1997	0	0	0	0.0054	0.236	0.7335	0.9118	1	1	1	1
1998	0	0	0	0.0145	0.1134	0.8077	0.9235	0.9981	1	1	1
1999	0	0	0	0.011	0.2357	0.5999	0.9393	0.9985	0.9975	1	1
2000	0	0	0	0.0151	0.199	0.7969	0.8947	0.9999	0.9986	1	1
2001	0	0	0	0.0062	0.2492	0.7624	0.9363	0.9579	0.9997	1	1
2002	0	0	0	0.014	0.1129	0.8076	0.9298	0.9997	0.9849	1	1
2003	0	0	0	0.0107	0.2482	0.6589	0.9435	0.9988	0.9994	1	1
2004	0	0	0	0.0057	0.2008	0.8114	0.9047	0.9999	0.9992	1	1
2005	0	0	0	0.0164	0.1222	0.7563	0.942	0.9874	0.9999	1	1
2006	0	0	0	0.0154	0.2677	0.6261	0.9311	0.9998	0.9966	1	1

The modelled ogives are much lower than the 3-year running average for ages 4 and 5. The proportion modelled/3-year running average maturity is on average over the whole time series 0.17 and 0.48 for ages 4 and 5, respectively. For age groups 6-9 the proportions are close to one (1.03, 1.08, 1.10 and 1.03).

Using the new ogives in the updated 2007 assessment, the over all effect on the estimated SSB is a reduction from about 810 000 tons to 700 000 tons (14 %) in the last assessment year (2006). At the moment with a record high SSB this difference will not effect the advice, but should the SSB approach the PA level (220 000 tonnes), it could become critical for the advice.

We therefore recommend that AFWG consider using the modelled maturity at age for the period from 1985 and onwards.

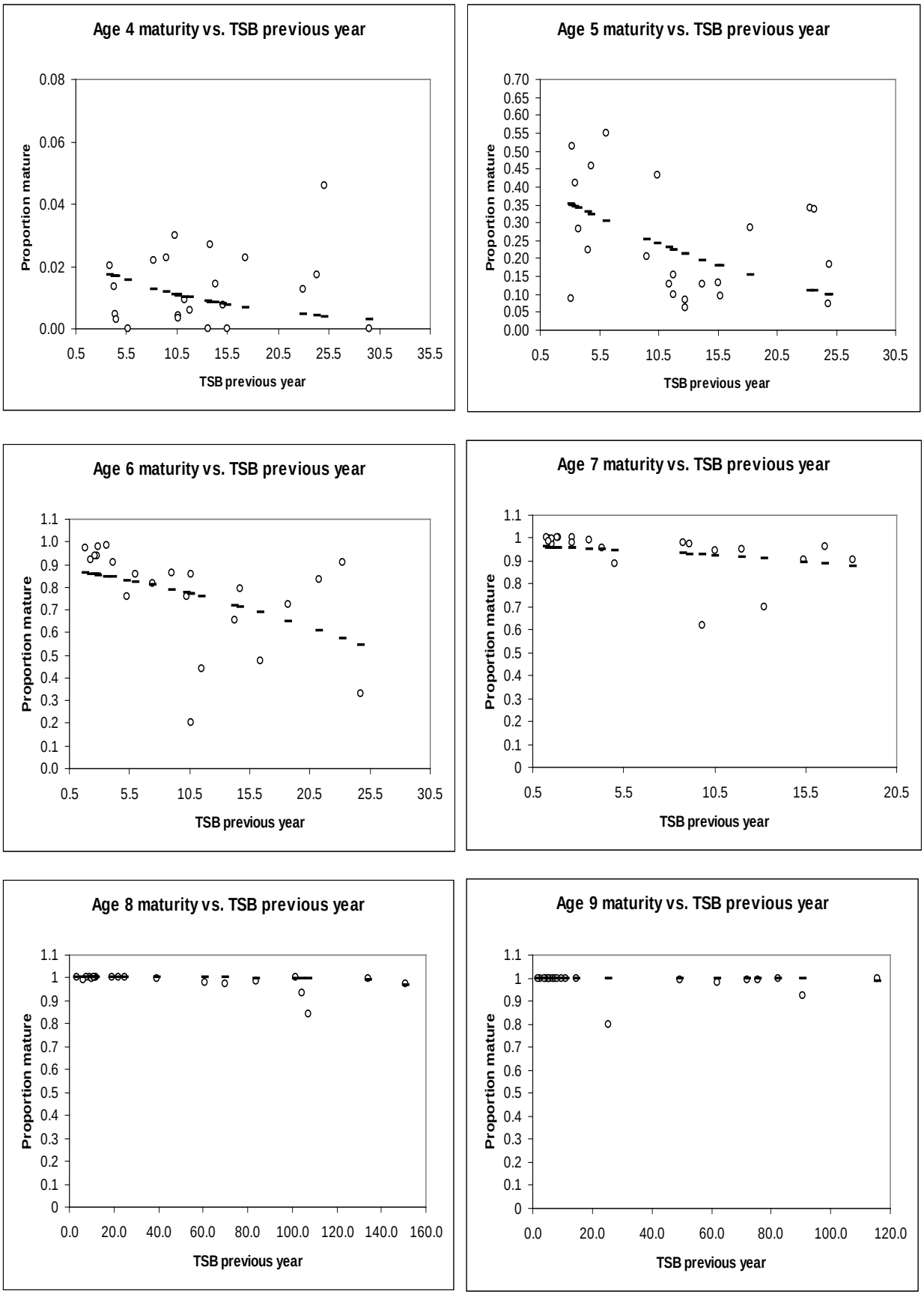


Figure 1. Model fits for age groups 4-9

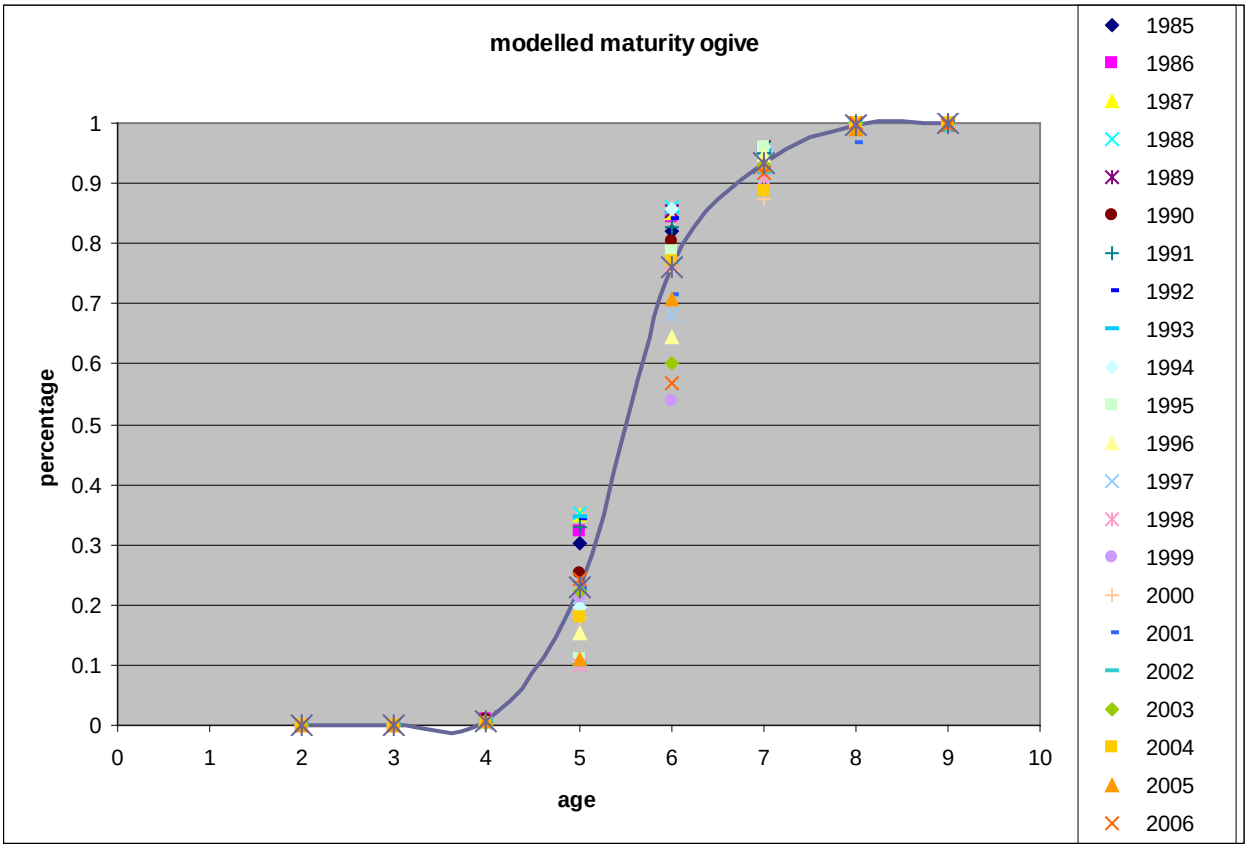
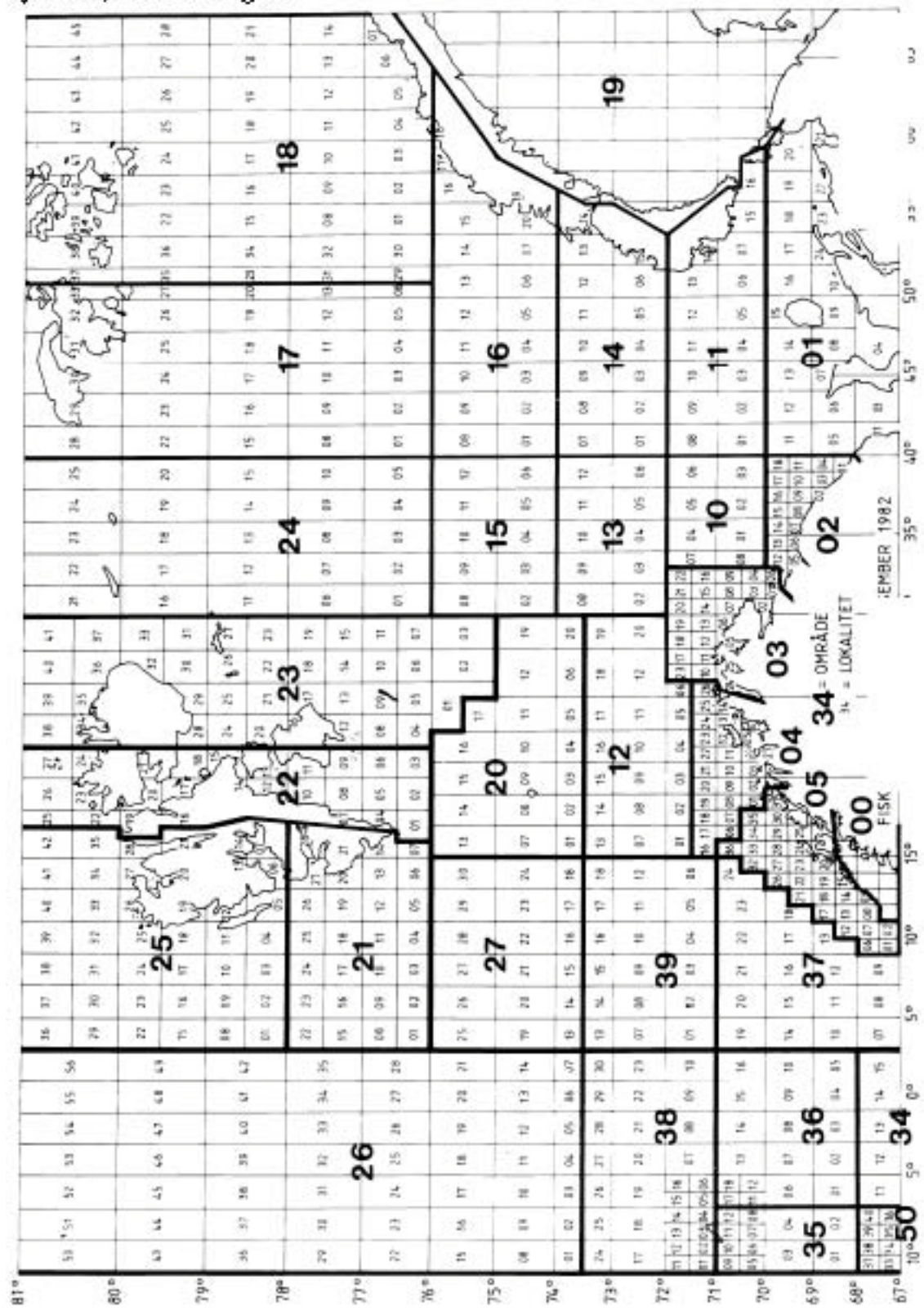


Figure 2 Annual and average modelled maturity ogive 1985-2006.

System 2, statistical region



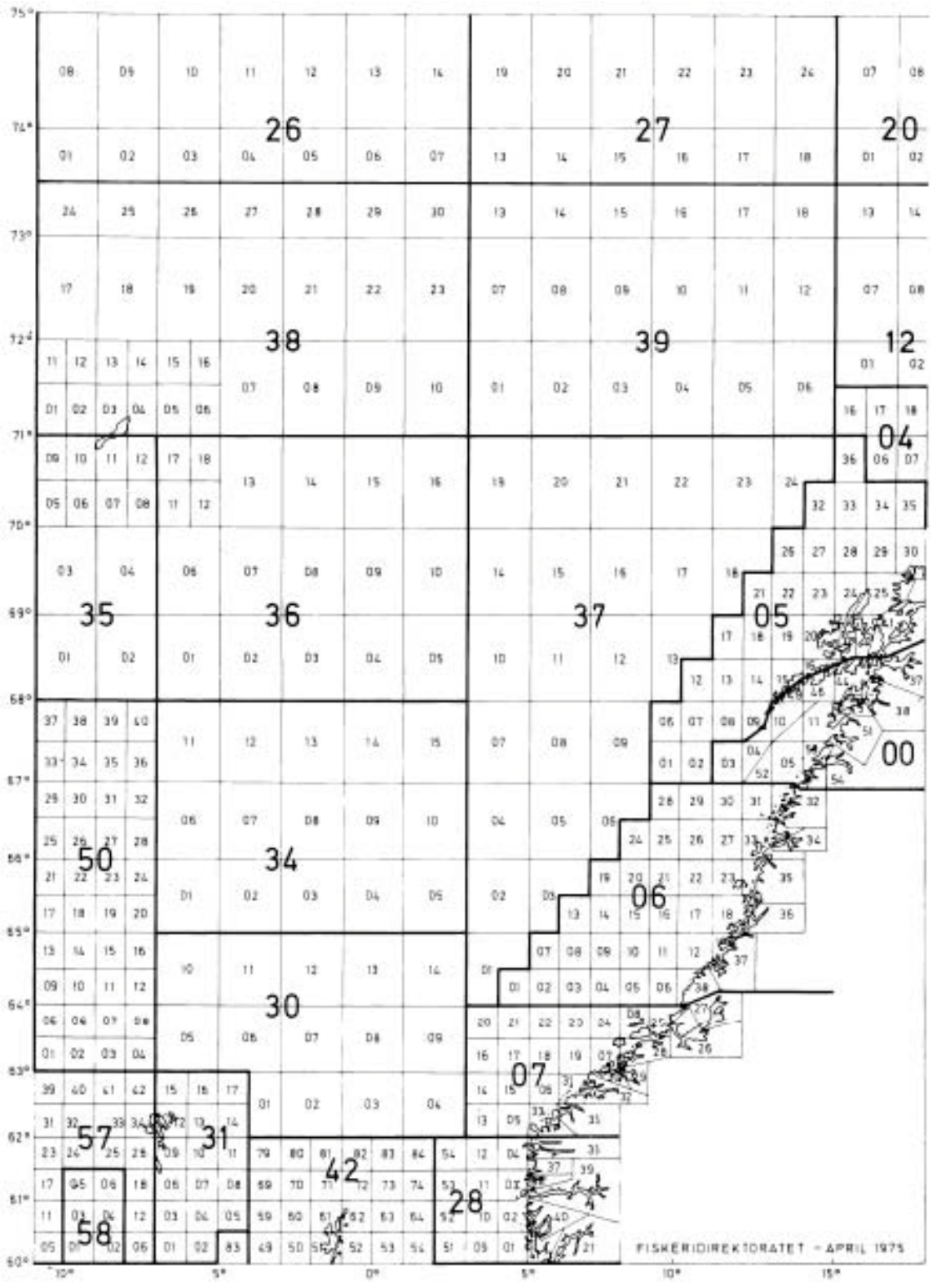


Figure 3. Statistical regions set by Norwegian Fishery Directorate.

References

Aglen, A., Drevetnyak, K., Jakobsen, T., Korsbrekke, K., Lepesevich, Y., Mehl, S., Nakken, O. and Nedreaas, K. 2001. Investigations on demersal fish in the Barents Sea winter 2000. Detailed report. IMR-PINRO Joint Report Series no. 5, Bergen, Murmansk. 74 pp.

Bogstad, B., Aglen, A., Skagen, D.W and Åsnes, M.N., IMR, Bergen, Norway; Kovalev, Y. and Yaragina, N.A., PINRO, Murmansk, Russia. 2004. Evaluation of the proposed harvest control rule for Northeast Arctic cod. Working Document #3, AFWG 2004, Copenhagen 4-13 May 2004.

Kovalev, Y., and Bogstad, B. 2005. Evaluation of maximum long-term yield for Northeast Arctic. In V. Shibanov (ed.) Ecosystem dynamics and optimal long-term harvest in the Barents Sea fisheries. Proceedings of the 11th Russian-Norwegian Symposium, Murmansk 15-17 August 2005. IMR/PINRO Joint Report Series, No 2/2005. PINRO Press Murmansk 2005.